YOUNG RESEARCHER SYMPOSIUM 2012
BROOKHAVEN NATIONAL LABORATORY

Monte Carlo simulation techniques used in the study of different physics channels at the future eRHIC project

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BNL EIC Science Task Force

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BROOKHAVEN NATIONAL LABORATORY

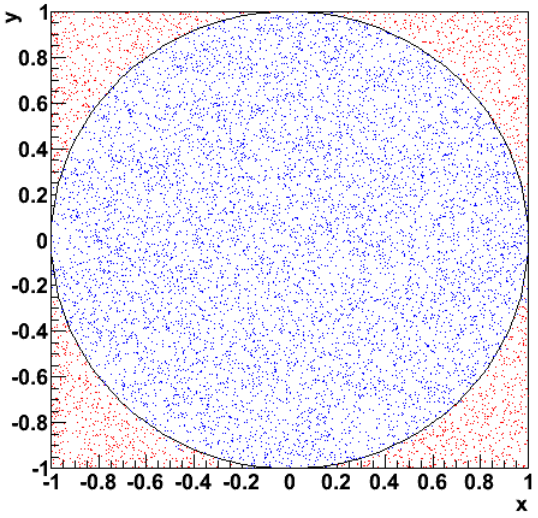
Outline

- Monte Carlo methods
- Monte Carlo simulation in Particle Physics
- The eRHIC project
  - Physics goals
  - Simulation of a golden measurement

Monte Carlo Simulation

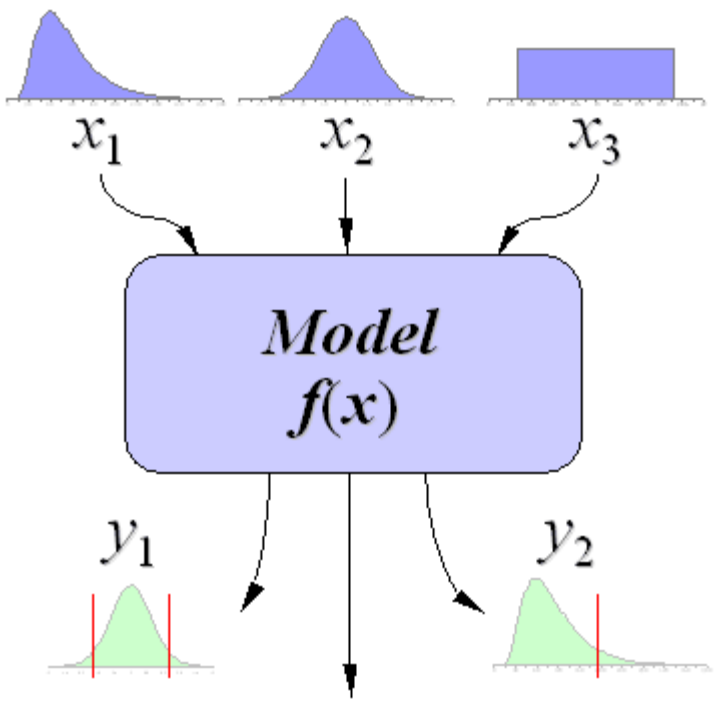
- The drunk man's dartboard
  - The drunk man's darts always fall everywhere within the square randomly
  - If a dart lies within the circle, it results in a score
  - What is the probability for our hero to get a score?

- The simulation approach
  - Generate 2 independent uniformly distributed random numbers x and y
  - Points in $x^2+y^2<R^2$ marked as blue, otherwise red
  - Given a certain total trials N_{total}, count number of blue points N_{blue}, Prob=N_{blue}/N_{total}.
  - With N_{total}=5000, we get the probability 0.78



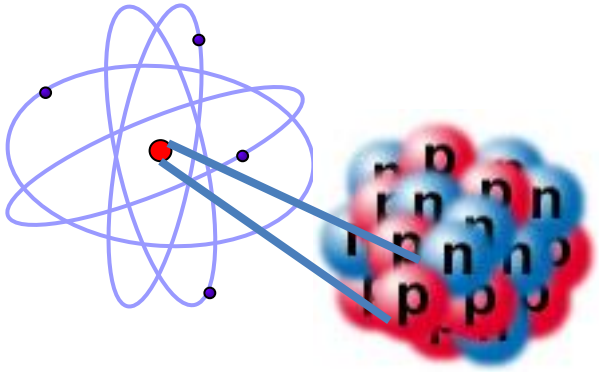
Monte Carlo Simulation

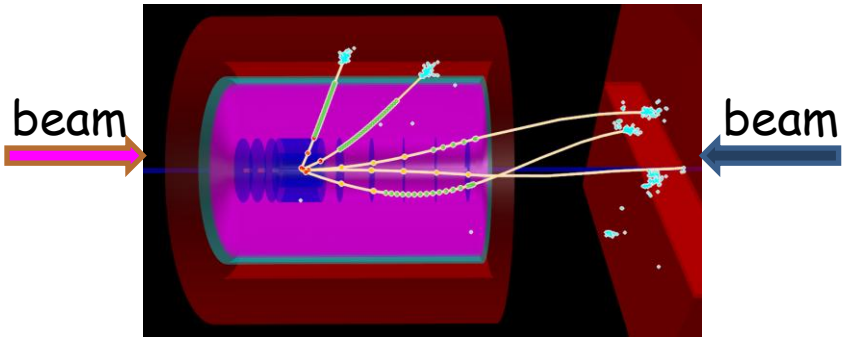
- Define a domain of possible inputs
- Generate the inputs from a specified probability distribution
- Perform a calculation according to the problem to be solved
- Repeat above steps several times
- Aggregate the results



Powerful to treat those models with stochastic input.

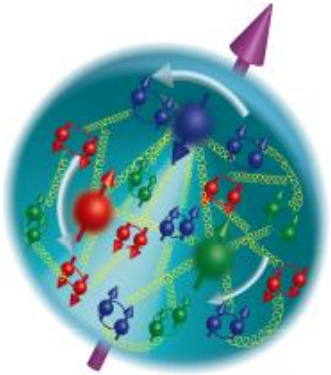
Monte Carlo Simulation in Particle Physics



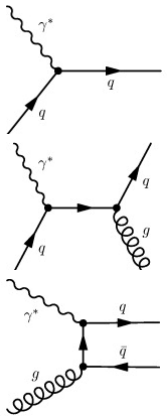


What we might see in a detector

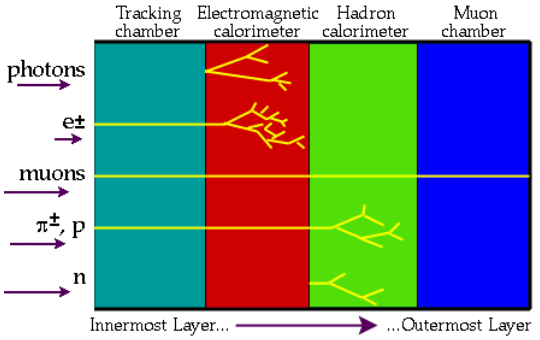
Nucleon structure



Physics channels



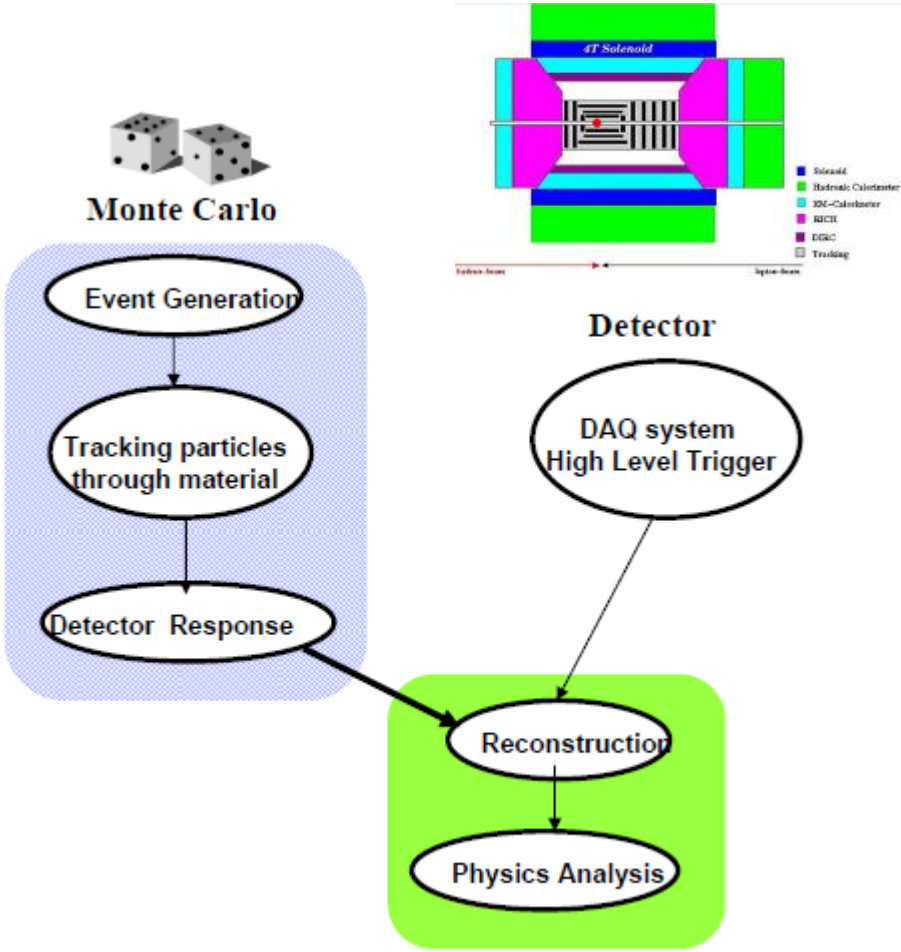
Detector response



How do we understand it

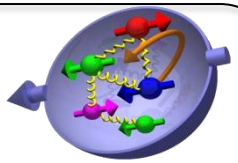
Monte Carlo and Particle Physics

- Monte Carlo simulation in particle physics
  - Event generation
  - Detector response
- When an experiment is running
  - Estimate background, efficiencies
  - Calibrate the detector performance
- When an experiment is being designed
  - Detector design and optimization (cost/benefits ratio)
  - Simulate new physics measurements



eRHIC: the New Frontier in Particle Physics

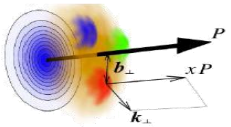
Spin physics



determine quark and gluon Contributions to the proton spin at last

For more info on spin physics see D. Smirnov's talk and poster

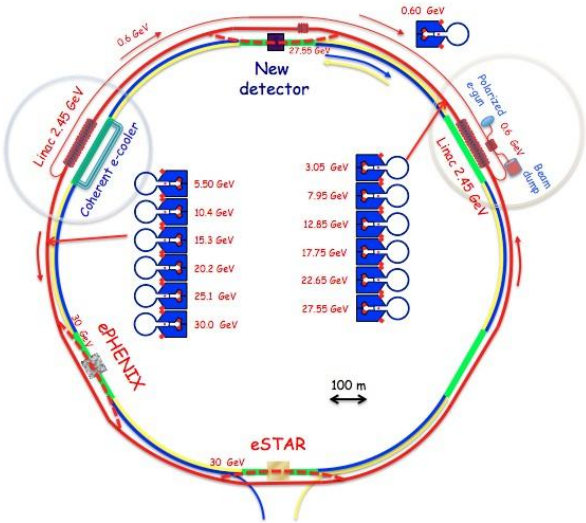
Nucleon imaging



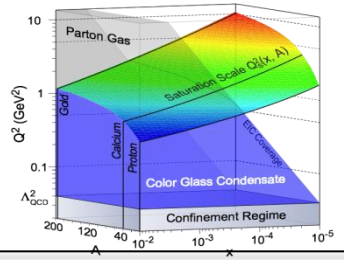
what is the spatial distribution of quarks and gluons in nucleons/nuclei

For more info on nucleon imaging see S. Fazio's talk and poster

For more info on eRHIC detector/accelerator see B. Di Ruzza's talk and poster



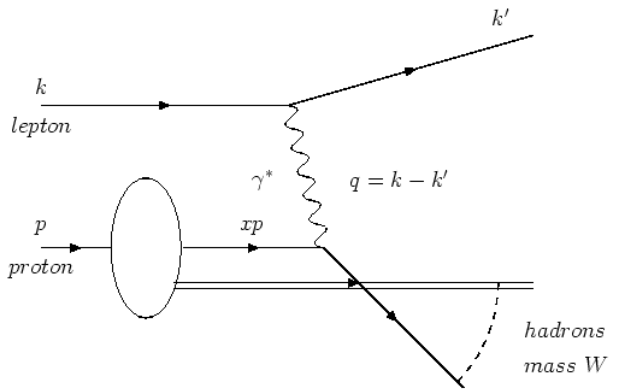
Physics of strong color fields

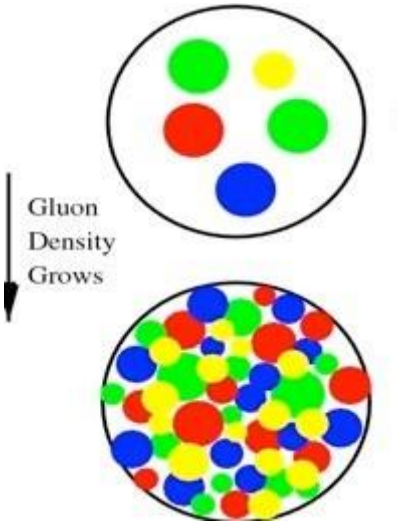


understand in detail the transition to the non-linear regime of strong gluon fields and the physics of saturation

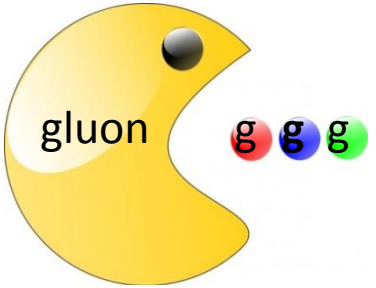
Saturation physics

Deep inelastic scattering

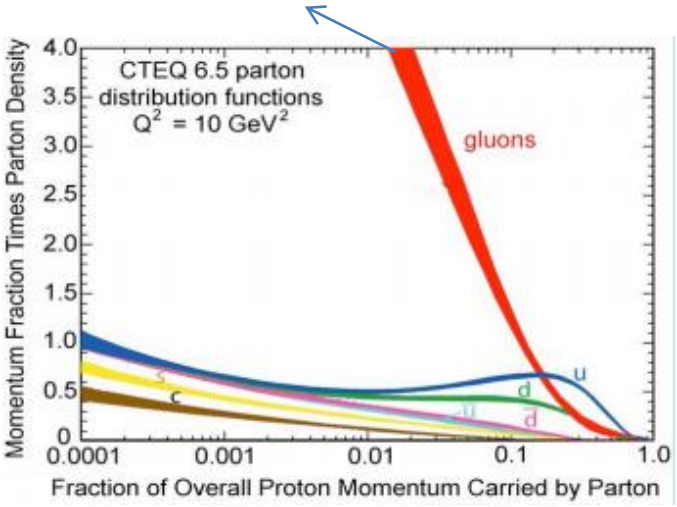


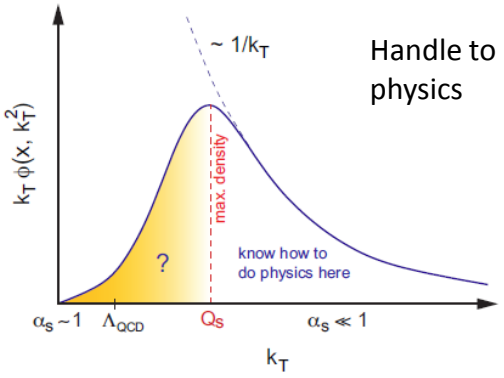


saturated



Need to be tamed





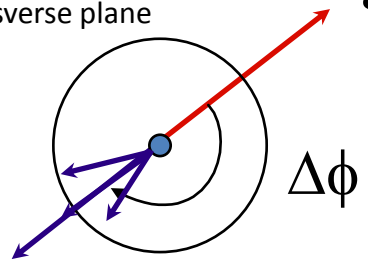
Handle to saturation physics

A golden measurement

$$C(\Delta\phi) = \frac{1}{N^{trig}} \frac{dN^{asso}}{d\Delta\phi}$$

- ✓ unique
- ✓ feasible
- ✓ relevant

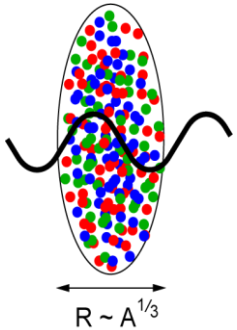
Beam view
or transverse plane



(usually leading pt)

Nearside peak: delivers jet fragmentation information from final state

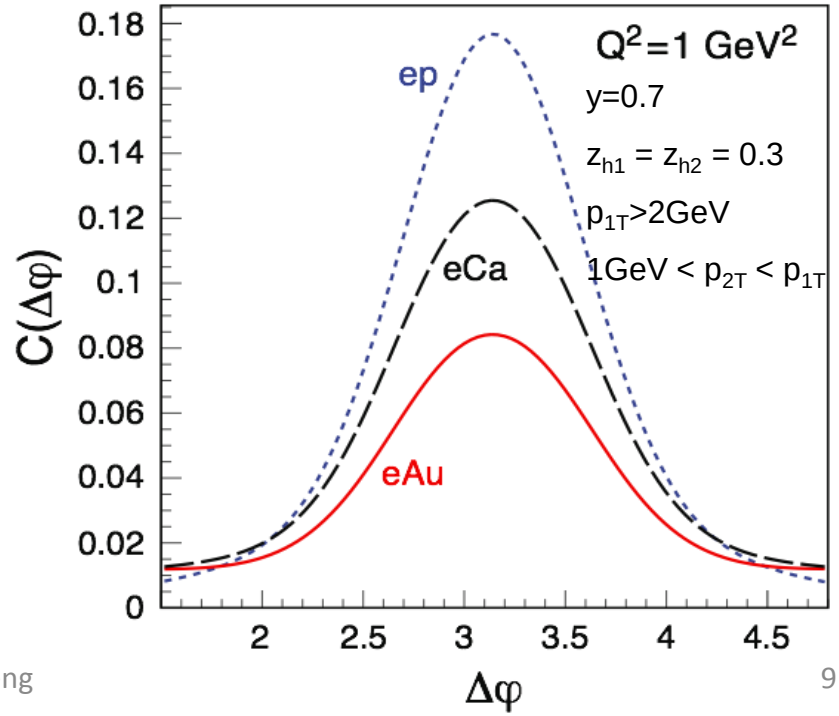
Awayside peak: related with the medium k_T kick from initial state



Pocket formula: $Q_s^2 \sim A^{1/3} x^{-0.3}$

Nucleus is an amplifier

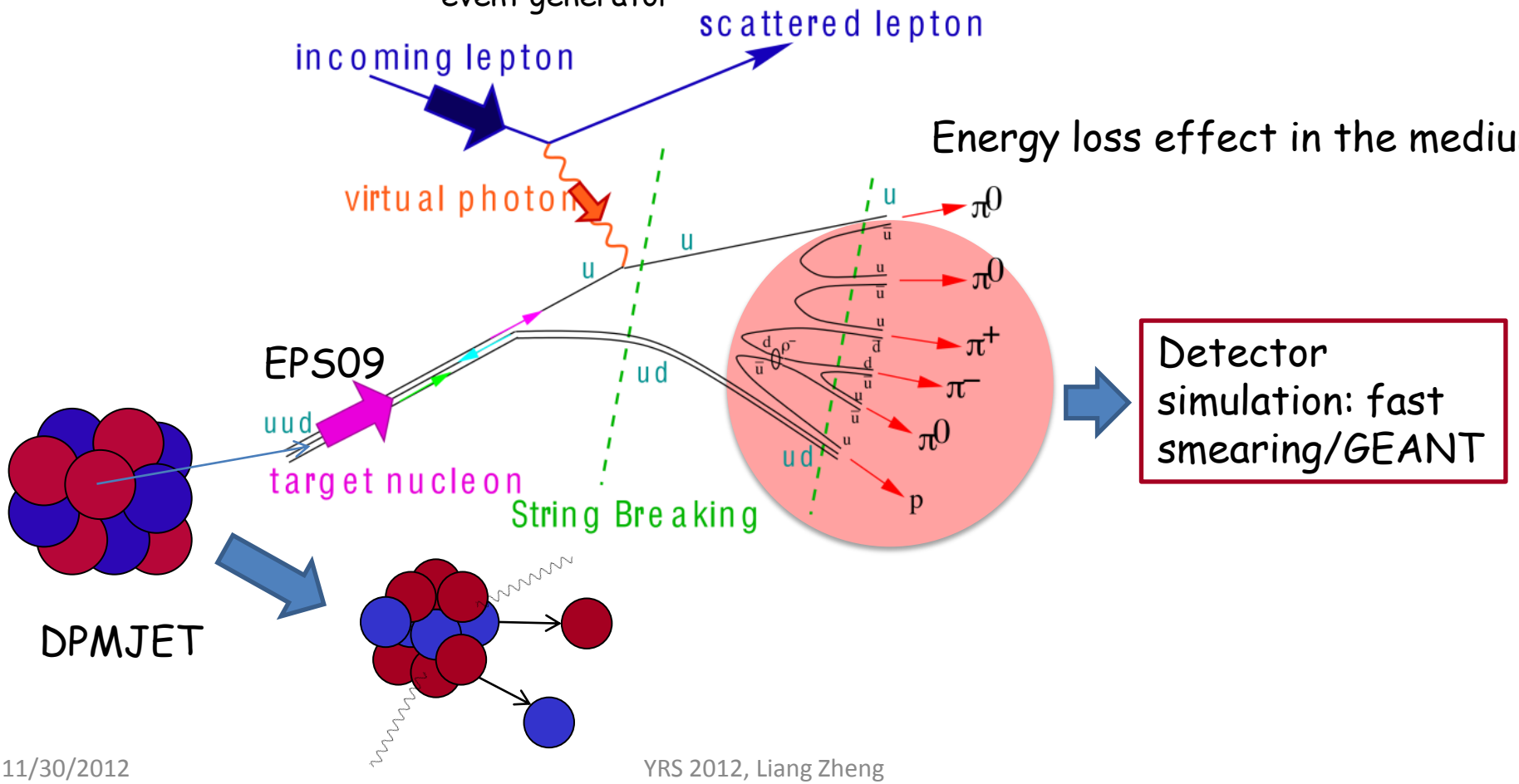
Xiao, Dominguez, Yuan 2011/2012



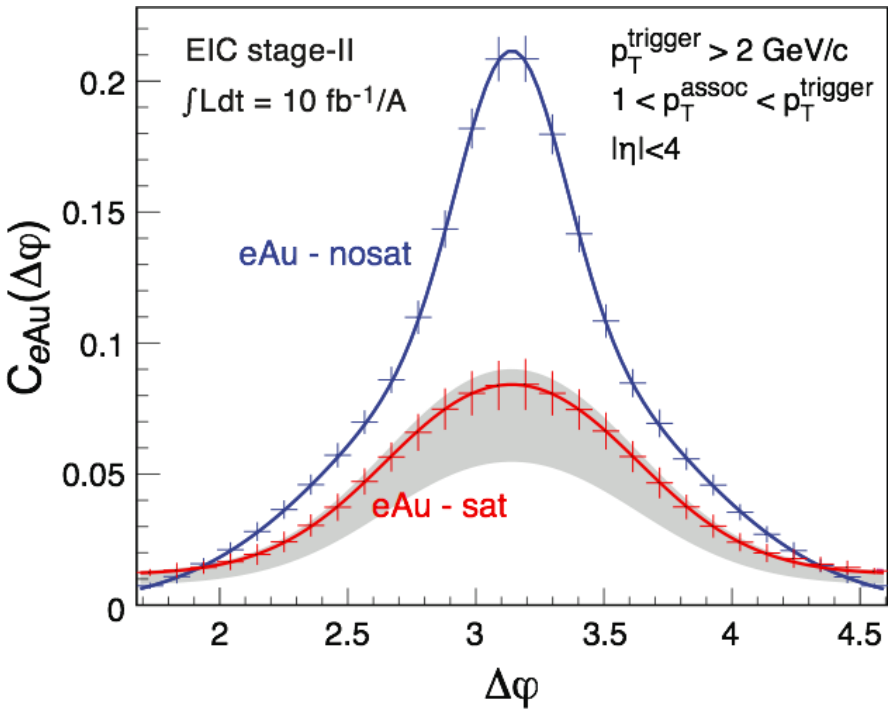
Our simulation strategy

Event generator:
From e+p to e+A

PYTHIA: well developed e+p event generator



Simulation results for dihadron correlations in eA



Saturation expectation: back to back peak washed out by multiple gluon interactions.

No saturation: peak persists without saturation ep->eA.

Saturation and No saturation are easy to resolve with a few months running.

Summary

- Monte Carlo simulation is a powerful and indispensible tool to particle physics experiment.
- We are using it to help us build up eRHIC and rise to the challenge in the design of such a new machine.
- This new machine if achieved would serve as a source to extremely extend our knowledge of the universe.

Acknowledgements

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Working groups: ep, eA, detector and machine design

eRHIC-homepage: https://wiki.bnl.gov/eic/index.php/Main_Page